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PROGRESS REPORT ON THE GEOLOGY, HYDROGEOLOGY, AND WATER QUALITY OF THE MINE AREA
Molycorp Facility
Taos County, New Mexico

prepared for
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Progress Report on the Geology, Hydrogeology, And Water Quality of the Mine Area

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1.0 INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

The Molycorp molybdenum mine is located on the western slope of the Taos Range of the Sangre de Cristo Mountains, Taos County in north-central New Mexico (Figure 1). The Mine Area lies north of the Red River and State Highway 38 which connects the mine area with the Town of Red River (6 miles to the east) and the Town of Questa (6 miles to the west). For the purposes of this report, the study area has been defined as the ***Mine Area***, which consists of extraction, processing, and rock-waste deposition activities. The significant features associated with the Mine Area are shown on Figure 2.

Mining for molybdenum began in the Questa area between 1916 to 1920. The nature of mining activities progressed form the original underground workings to open-pit operations (beginning in 1964-65), and back to the more recent underground mining (beginning in 1979-1983). Mine waste-rock dumps were emplaced during the 1970s and 1980s when the open pit was excavated. The mine went on temporary standby status in 1986 until economic conditions improve for the molybdenum market. Mine dewatering resumed in July 1994 in anticipation of potential reactivation of mining activities.

The Molycorp mining operations have been both extractive in nature (the Mine Area) and simultaneously depositional (the Mine Area waste-rock dumps and the Tailings Area). Large-scale extractive or depositional activities normally will have an impact on a natural environment. Molycorp has been both proactive and responsive to examination of the environmental impacts resulting from their activities. In the Mine Area, any adverse water-quality impacts are exacerbated, if not exceeded, by natural impacts (e.g.-acid runoff from hydrothermal scars). Water-quality data from several sources, including the Red River sewage treatment plant well, Hanson Creek, and Hot-N-Tot Creek indicate significant natural contributions to surface-water and ground-water quality degradation.

In 1989, Molycorp retained the services of South Pass Resources, Inc. (*SPRI*) to evaluate impacts of past and present Molycorp operations on ground-water and surface-water quality. The dominant environmental concerns are two-fold:

- What impacts, if any, have mining operations had on surface-water (Red River) or ground-water quality?
- What percentage of any surface-water or ground-water quality degradation is from natural (versus mining-related) sources?

These issues are under study by consultants currently retained by Molycorp (including SPRI, Vail Engineering, and Steffen Robertson & Kirsten). Previous studies by SPRI, Dames and Moore, Harding-Lawson, Water Resource Associates, Geocon, Vail and Associates, ENSR, and others have focused on definition of the geologic, hydrogeologic, water quality, and hydrologic characteristics in and about the Molycorp facilities. Of particular emphasis has been definition of those naturally-occurring physical and chemical parameters that control real or potential contaminant migration pathways and concentrations.

SPRI's most recent (Summer and Fall 1994) activities have involved the design, installation, and testing of 12 new monitor wells in the Mine Area. This report presents a detailed discussion of the results of the 1994 investigation, and of previous investigations, and an evaluation of recent geologic, hydrogeologic, and water-quality data.

1.2 SUMMARY OF FALL 1994 AND PREVIOUS INVESTIGATIONS

Beginning on July 11, 1994, SPRI overviewed the design, installation, and testing of 12 new monitor/extraction wells in the Mine Area. The purpose of this investigation was to:

- characterize the water quality of naturally occurring ground water and seeps and compare these data to seepage from mining activities; and
- characterize the geologic controls on fluid movement.

In addition, the drawdown associated with the cone of depression from dewatering of the mine is being monitored within the newly-installed wells. It will take a year or more of monitoring before drawdown rates can be quantified; some additional monitor wells may be required.

The wells that were installed during the 1994 investigation, and the details of their installation and testing, are summarized below. The locations of these wells and other wells installed in the Mine Area are shown on Figure 2.

Monitor/Extraction Wells Installed in Mine Area July/August 1994			
Well No.	**Total Depth (feet)**	**Screened Interval (feet)**	**Well Completed In**
MMW-2	68	38 - 58	mudflow
MMW-3	145	65 - 115	andesite bedrock
MMW-7	161	86 - 161	andesite bedrock
MMW-8A	161	125 - 161	andesite bedrock
MMW-8B	129	67 - 117	mudflow
MMW-10A	144	79 - 130	alluvial gravel/ sand overlying quartz monzonite bedrock
MMW-10B	189	133 - 189	quartz monzonite bedrock
MMW-10C	50	31.5 - 50	mudflow
MMW-11	185	145 - 185	quartz monzonite bedrock
MMW-13	148	105 - 148	sandy gravel, gravelly sand overlying quartz monzonite
MMW-14	75	48 - 75	sandy gravel gravelly sand
MMW-16	98	45 - 98	sandy gravel gravelly sand overlying light grey granite

A partial listing of the other monitor and extraction wells in the Mine Area that pre-date SPRI field activities are summarized below. (Note: a complete list of all wells located in the study area is unknown at this time.)

Other Wells Located in the Mine Area (Partial Listing)		
Well No.	**Total Depth (feet)**	**Year Installed**
Mill Well 1A-1	176	1977
Mill Well No. 1	150	1962
Columbine No. 1	89	1965
Columbine No. 2	140	1965
Columbine No. 1 redrill	153	1971

2.0 GEOLOGY AND HYDROGEOLOGY

2.1 GENERAL GEOLOGIC SETTING

The major sources of geologic data for the Questa Mine area are Schilling (1956); Rehrig (1969), Lipman (1981), Bookstrom (1981), and numerous unpublished maps, cross-sections, and reports by Molycorp geologists. A common thread to all of these geologic studies is that the mineralization at Questa was related to Tertiary magnetism and hydrothermal solutions focused along an east- to northeast-trending structural zone. This structural zone is variously interpreted as part of a graben (Schilling, 1956); as a zone of intense faulting (called the Red River Structural Zone by Rehrig, 1969); and the southern part of the outer ring fracture zone that formed the outer wall of the Questa caldera (Lipmann, 1981; Bookstrom, 1981).

The development of the caldera and the associated volcanic and intrusive rocks was a late Oligocene to Middle Miocene event (27.2 to 22 million years before present) that was concurrent to and overlapped the regional rifting associated with the Rio Grande Rift System. The range-bounding high-angle fault along the west side of the Sangre de Cristo Mountains (about 5 miles west of the mine) is related to regional extension across the Rio Grande Rift and the uplift of the range in Mid-Tertiary time. At least the later movements along this range-front fault are younger than the caldera structure because the outer ring fracture zone is truncated by the range-front fault.

2.2 MINE AREA GEOLOGY AND HYDROGEOLOGY

Geology

The Mine Area is composed of Pre-Cambrian igneous, metasedimentary, metavolcanic, and other metamorphic rocks, overlain by a thick sequence of Tertiary ashflow tuffs and andesitic lava flows. These rock types have been intruded by granitic rocks, forming dikes, and elongated intrusions. Mineralized quartz veins in the Mine Aplite (i.e., finely crystalline granite) and in the adjacent intruded volcanics were formed during a late magmatic, post-caldera hydrothermal stage. The Mine Area is within a northeast- to east-trending structural rift zone that forms the south side of the Questa caldera. This structural rift zone contains numerous dikes and mineral veins. Fractures and fault discontinuities are widely varied, as illustrated on a geologic cross-section (Figure 3), and include:

- high-angle faults and joints;
- low-angle faults; and

- contact-zone fractures between different rock units.

The mined ore deposits consist of molybdenite-bearing quartz veins.

Hydrogeology

In the Mine Area, the most significant controls to fluid movement appear to be preferred channels within mud flows, location and degree of geologic discontinuities (faults, joints, fractures), man-made fluctuations of the water table north of the Red River, and hydraulic conductivity differences between mine waste-rock, bedrock, and valley-fill (mudflow or alluvium). Water-quality degradation of the Red River in the Mine Area has been found to be heavily controlled by natural processes and is influenced locally from byproducts of mining.

Hydrogeologic units include a basement (Pre-Cambrian) aquitard, overlain by volcanics and sedimentary rock aquifers and/or valley-fill mudflow and alluvial valley-fill aquifers. Hydrothermal scar materials of low hydraulic conductivity are scattered over the area. Mine waste dumps contain perched aquifers.

The natural ground-water gradients are toward the Red River. Mine dewatering operations have created a cone of depression around the underground mine workings. The primary hydrologic linkage between up-gradient sources and the river is the fan delta deposits at the mouths of tributary canyons at Capulin Canyon and Sugar Shack South. The 12 monitor/extraction wells installed by SPRI in Fall 1994 were screened in fan delta and bedrock aquifers, and were constructed at sites near the mouths of tributary canyons to evaluate these linkages. Water-quality sampling and water-level measurements were made in cooperation with the New Mexico Environmental Improvement Department (EID) in November 1994.

In the Mine Area, low pH, high total dissolved solids (TDS), and high sulfate characterize the natural springs and seeps as well as surface water in drainages crossing hydrothermal scar areas. Analytical results of water quality sampling along and adjacent to the Red River indicates both natural and mine-related seepage affect the water quality of the Red River. Deep underground mine water has a slightly alkaline pH plus slightly elevated levels of TDS and sulfate.

Water in the unsaturated zone, water in the perched-water zones, and ground water move from sources to discharge points. Sources of this water are both natural and mine-related: infiltration, surface run-off, and seepage from natural springs and mine-constructed waste-rock piles. The discharge points consist of the deep underground mine, the Red River, and (via slurry line) the Tailings Area ponds. Water that arrives at the discharge points consists of natural acidic drainage mixed with varying amounts of waste-rock dump-related water.

Naturally acidic waters have been in transit through the same system, excluding seepage barriers, for thousands of years as is evident from limonite-cemented alluvial and mudflow deposits.

Perched water can form near the base of the waste-rock dumps. Perched water can also form in zones of fractured bedrock above the main water table and above clay intervals in the valley-fill. Bedrock seeps, such as the seeps at Cabin Springs near the river, may be from a perched bedrock zone.

Dewatering of the new underground mine (1979 to 1992 and resumed in July 1994) has created a cone of depression that appears to extend in some places to the Red River. The original cone of depression may have captured much of the natural and mine-related discharge. However, Capulin Canyon appears to lie outside the zone of influence of dewatering. Also, the Cabin Spring seepage (which may be perched) may not be impacted by the dewatering cone of depression.

The impact of the current mine dewatering on recharge of mine-related seepage to the Red River cannot be properly evaluated until after at least one year of data collection including monthly water-level measurements and quarterly water-quality analysis (similar to data collection of November 1994). Bladder pumps were used to collect water-quality samples at all of the mine monitor/extraction wells because (with some exception) the wells appear to be low yield (less than a few gallons per minute). The known exceptions are MMW-11 (bedrock well in a fracture zone), which pumped at a rate of more than 60 gpm, and MMW-10A (valley-fill well), which pumped at 140 gpm with 3 feet of drawdown. Because the existing extraction wells in the Mine Area tend to be low-yield wells, their capacity to control seepage by pumping is limited.

Appendices A and B contain more detailed discussions of the Mine Area geology and hydrogeology. Appendix C contains geologic logs for wells emplaced during SPRI's 1994 investigation. Appendix D contains data and discussions on water quality.

3.0 RESULTS AND DISCUSSION OF SPRI SUMMER/FALL 1994 FIELD ACTIVITIES

3.1 WELL EMPLACEMENTS

To identify and evaluate the presence of potential hydrogeologic connections between the waste-rock dumps, down-gradient aquifers, and the Red River, aerial photographs were used to locate the monitor/extraction wells as close as possible to the pre-1963 valley bottom. [In a number of areas, waste-rock dumps and/or mine cut-and-fill operations have subsequently covered these drainages. The fan delta deposits (alluvial sediments and mudflow deposits, collectively called the *valley-fill aquifer*) occur at the mouths of tributary valleys to the Red River (see Figure 4).]

The equipment used to drill the monitor/extraction wells consisted of a casing drive system using 8-inch and 12-inch inside diameter (ID) threaded drive casing. A casing drive shoe was attached to the base of the casing driver and remained at the bottom of the cased hole after hydraulic jacks extracted the drive casing. Well construction and placement of annular materials were accomplished inside the drive casing, limiting the well casing to 8 inches or less inside the 12-inch drive casing and 6 inches or less inside the 8-inch drive casing. A downhole air hammer and hammer bit were used to drill through boulders and bedrock. The drill equipment consisted of a 15W Gardner Denver Tophead drive chain pulldown drill rig, water truck, pipe truck, air compressor truck (primary), tag-along air compressor (secondary), and hydraulic jacks' truck.

All wells that had water in the borehole were developed by either pneumatic downhole bladder pump, bailing, or electric submersible pump. Low-yield wells were pumped using the pneumatic bladder pumps (for their design protections against pump burnup). The medium-yield wells were pumped by continuous bailing with an 18-gallon bailer. The bailing operation used a hydraulic powered 5T Smeal pump truck to raise and lower the bailer. Bailing rates were adjusted to fit each well's yield so as to allow for baildown without undue interruption of the extraction rate. High-yield wells were pumped with either one horsepower (hp) or 5 hp electric submersible well pumps. The actual high-end pumping rate varied with head considerations, but the 5 hp pump would usually pump up to 50 gallons per minute.

When the locations of the monitor wells were established and surveyed for elevation by Molycorp staff, elevations for wells with protruding casing vaults were taken at the top of the casing and elevations for wells with flush-mounted vaults were taken at the top of the cement pad. All measuring point elevations have been corrected to read from the top of the cement pad.

3.2 WATER LEVELS AND HYDRAULIC CONNECTIONS

SPRI overviewed the installation of 12 new monitor wells during the 1994 investigation (refer to Figures 2 and 10 for locations). These wells and their hydrologic characteristics are described below.

<u>Wells MMW-14 and MMW-16</u>

These wells, which are located in the fan delta or valley-fill deposits and the immediately underlying bedrock opposite the Sulphur Gulch and Spring Gulch area, are dry. The open pit (Sulphur Gulch) and the decline that passes under lower Sulphur Gulch may capture most of the discharge from the drainage basin. (These wells are not deep enough to intersect the cone of depression if it extends into this area.)

<u>Well MMW-13</u>

This well was drilled opposite the Middle Dump and extended initially into bedrock (25 feet); it was completed as a valley-fill well since the bedrock was dry. It is difficult to distinguish reworked valley-fill from in-situ valley-fill by drill cuttings alone. Berms were constructed across the lower parts of some tributary valleys prior to dump construction. Using elevations for the pre-berm surface from the 1963 USGS topographic map (Questa, NM 7.5 Minute Quadrangle Map) and more recent mine topographic maps, the upper 50 to 70 feet of sandy gravel at MMW-13 appear to be berm material. The lower 15 feet of the valley-fill was saturated. The water-level elevation at this well is low (7,963 feet) when compared to the stream bed elevation opposite the well (7,990 to 8,000 feet). This water-level elevation has changed less than 1.0 foot over the five-month period since construction. The water level will continue to be monitored for evidence of additional drawdown related to the mine cone of depression.

<u>Wells MMW-10A, B, C</u>

These wells are located below the toe of Sugar Shack South Dump. The elevation of the Red River opposite these wells is between 7,910 and 7,920 feet. The water quality of Portal Springs (a series of river bank seeps along the north side of the river) is commensurate with natural acidic sources and/or waste-rock dumps. The eastern most seep (located just west of the MMW-10 wells) has an estimated elevation of 7,915 feet. As discussed later in this section, these seeps are believed to represent the top of the potentiometric surface at the river. Water-level elevations at the three MMW-10 wells are slightly above 7,917 feet.

Monitor well MMW-10A is screened in the lower part of the valley-fill, immediately above bedrock. The borehole log indicates that the fill here is a mixture of fluvial sands and gravel and mudflow deposits. Clay beds interbedded in the valley-fill probably resulted from deposition in lakes formed behind contemporaneous mudflows that blocked the Red River Valley. The aquifer test results discussed in Section 3.3 indicate that this well, if fully stressed, may produce several hundred gallons per minute from the saturated sands and gravels.

MMW-10B is screened in bedrock just below the valley-fill, but the water-level elevation (7,917 feet) is 112 feet above the contact, indicative of a strong upward gradient. This water-level elevation is close to that of the two valley-fill wells which, since the bedrock is highly fractured below the fill, could also be interpreted to mean that the fill and the shallow bedrock are in hydraulic continuity. As discussed in Section 3.3, the aquifer test at MMW-10A established some hydraulic connection between the valley-fill aquifer and the underlying bedrock aquifer (MMW-10B) because both wells gave drawdown effects during the test. The head relationship between the valley-fill and the bedrock aquifers may have a seasonal component with higher heads in the bedrock during spring recharge.

MMW-10C is screened in the upper part of the valley-fill, just above a thick clay bed. It is conceivable that MMW-10C intercepts a perched zone, and the configuration of the perched water table is not dependent on the main water table. A more likely explanation is that the clay beds (just below the total depth for MMW-10C) retarded vertical flow and, because of the short duration of the aquifer test (100 minutes), there was very little drawdown at MMW-10C. An interpretation is that MMW-10C and MMW-10A are part of a continuous zone of saturation and that the clay bed is the cause of the lack of response during the aquifer test.

Well MMW-11

MMW-11 was completed in the upper part of the bedrock aquifer, just south of the toe of Sugar Shack South Dump. During the drilling of this well, the lower part of the dump material was described as moist, but free water (described as dark turbid water) did not appear until 93 feet. This description corresponds with the base of the dump material. Immediately underlying the dump material is a thin sandy gravel followed by 10 feet of gravelly clay. Small amounts of water [a few gallons per minute (gpm)] were reportedly produced throughout the valley-fill, but because a mixture of foam and water was being injected during drilling, the extent of saturation in the valley-fill is unknown. It is possible that the water at 93 feet infiltrated from the overlying dump material and represents a thin perched zone. The water-level elevation for the bedrock aquifer at MMW-11 is 7,915 feet, or 58 feet above the valley-fill and bedrock contact. This indicates a strong upward gradient which would be expected near the zone of discharge in the Red River valley. The water-level elevation for the valley-fill aquifer at MMW-11 is not known.

During the development (using air lift) of MMW-11, the bedrock aquifer had a pumping rate (Q) of 60 gpm with less than one (1) foot of drawdown (s). According to Huntley et al. (1992), the use of specific capacity formulas based on alluvial aquifer studies can be used to estimate transmissivity (T) for fractured rock. Using the equation:

$$T = K\left(\frac{Q}{s}\right)^{1.18}$$

where Q = 60 gpm
s = 1 foot, and
K = 38.9 [a conversion factor from Table 1 (Huntley et al., 1992); NOTE: This K is not equal to permeability]

a transmissivity (T) of 4,877 ft^2/day (36,479 gpd/ft) was calculated. (NOTE: The factor to convert from ft^2/day to gpd/ft is 7.48 gallons/foot.) This value contrasts with 90,000 gpd/ft based on the standard alluvial equation estimate:

$$T = \left(\frac{Q}{s}\right)1500$$

It is difficult to estimate hydraulic conductivity since the actual thickness of the aquifer is not known. If the thickness of bedrock aquifer open to the screen (40 feet) is used, a maximum value for K would be 912 gpd/ft^2. This value is close to the upper limit for fractured igneous rock (Freeze and Cherry, 1979) and could be a significant overestimation.

MMW-11 may be located near the outer edge of the cone of depression. Over the last five months, corresponding with dewatering of the underground mine, the water level at this well has shown fluctuations of less than 0.5 foot.

Figure 5 is a cross-section illustrating hydrogeologic relationships in the area of Sugar Shack South.

Wells MMW-8A and -8B

Monitor well MMW-8A (screened in bedrock) and MMW-8B (screened in valley-fill) are located on a fan delta deposit that filled an unnamed tributary valley in the area of Shaft No. 1. These wells are close to the river (within 250 feet). Water-level elevations for both wells are within the contour interval (10 feet) along the Red River opposite the well. It is not clear that the MMW-8 wells are within the cone of depression. Recharge from ground water beneath the river may balance discharge to the dewatering center, keeping water levels at about the same elevation. Additional monthly water-level measurements may help resolve the issue. The bedrock well (MMW-8A) has a slightly higher water level than the valley-fill well (MMW-8B), indicating a weak upward gradient.

Well MMW-7

This well (north of Shaft No. 1) was drilled to a depth of 161 feet and screened in bedrock. The water level here is 8,029 feet, which is approximately 550 feet or more above the current cone of depression. This well is screened in andesitic flow rock characterized by a series of low-angle north-dipping faults (Figure 3). Drill cuttings and drilling conditions indicated that the andesite is highly fractured. The potentiometric water level here is above the valley-fill/bedrock contacts. Valley-fill appeared to be unsaturated at MMW-7, and no perched zone within the fill was noted. MMW-7 appeared to have intercepted a perched zone within bedrock. This perched zone is confined to an interval of fractured rocks apparently associated with a series of low-angle structures. Figure 6 is a cross-section illustrating hydrogeological relationships at the MMW-7 and MMW-8 wells.

Upper Goathill Gulch drainage flows into the caved area. With the level of dewatering maintained below the elevation of the Red River, no monitor wells were constructed in the lower part of Goathill Gulch.

Wells MMW-2 and MMW-3

Well MMW-2 (in valley-fill) and MMW-3 (in bedrock) were drilled in the fan delta area in lower Capulin Canyon. Figure 7 is a cross-section illustrating the hydrogeologic relationships at MMW-2 and -3. Water-level elevations of these two wells are 90 to 100 feet above the level of the Red River at the mouth of the canyon. These elevations, if connected to a stream bed elevation farther upstream, are indicative of gaining conditions along the Red River. Based on the number of springs and seeps issuing from cutbanks along the river, the water table is likely to be at the stream bed. There is a weak upward gradient from the bedrock to the valley-fill; however, the water quality of the valley-fill ground water at MMW-2 is much closer to that of the surface flow in lower Capulin Canyon than to the water quality of the bedrock ground water. It also appears that the seeps near the confluence of Capulin with the Red River contain water that is chemically more similar to the valley-fill than the bedrock. Lower Capulin Canyon may be outside the influence of the dewatering at the mine.

Water Levels and the Red River

A number of the monitor wells show water-level elevations at or slightly below the elevation of the river opposite the well. Construction of a water-level contour map using data collected in November 1994 from both the valley-fill and bedrock wells (head elevations are very close for paired bedrock and valley-fill wells) revealed a cone of depression configuration that included MMW-8A and -8B, MMW-11, and MMW-13. Monitor wells MMW-10A, -10B, and -10C were considered to be outside the cone and related to a water table at or very close to the elevation of the stream bed.

A preliminary potentiometric water-level map (Figure 8) shows a cone of depression centered above the underground mine. (The southern edge of this cone is being monitored by the newly constructed wells.) A schematic of water-level changes in the area of the underground mine is shown on Figure 9.

3.3 AQUIFER TESTING

An aquifer test was conducted at MMW-10A at a pumping rate of 140 gpm (the pump was not capable of a higher rate). Although drawdown and recovery tests were completed at this rate, the valley-fill aquifer was not stressed. The drawdown leveled out after 10 minutes of pumping at 10.5 feet, indicating recharge balanced discharge. Transmissivity calculated from the aquifer test was considerably higher (123,200 gallons per day per foot - gpd/ft) than that calculated from the recovery test (32,139.1 gpd/ft). Recharge during the aquifer test strongly reduced the drawdown. The hydraulic conductivity from the recovery results is about 300 gallons per day per square foot (gpd/ft^2), which is in the range of values reported for sandy gravel. During the aquifer tests, water levels were monitored at MMW-10B and MMW-10C. Water level declined 6.0 feet in the bedrock well (MMW-10B), which suggests that the fractured bedrock below the valley-fill is in hydraulic continuity with the fill accounting for a common water level. The continuity between the water-level at MMW-10C and the other wells was thought to indicate continuous saturation from MMW-10C (total depth 58 feet) and the deeper wells. MMW-10C did appear to experience some drawdown (less than 1 foot), and it is possible that the change in depth-to-water at MMW-10C was a function of changes in barometric pressure. A perched zone above a clay unit may underlie MMW-10C (with a water table independent of the deeper saturated zone). However, the clay may have

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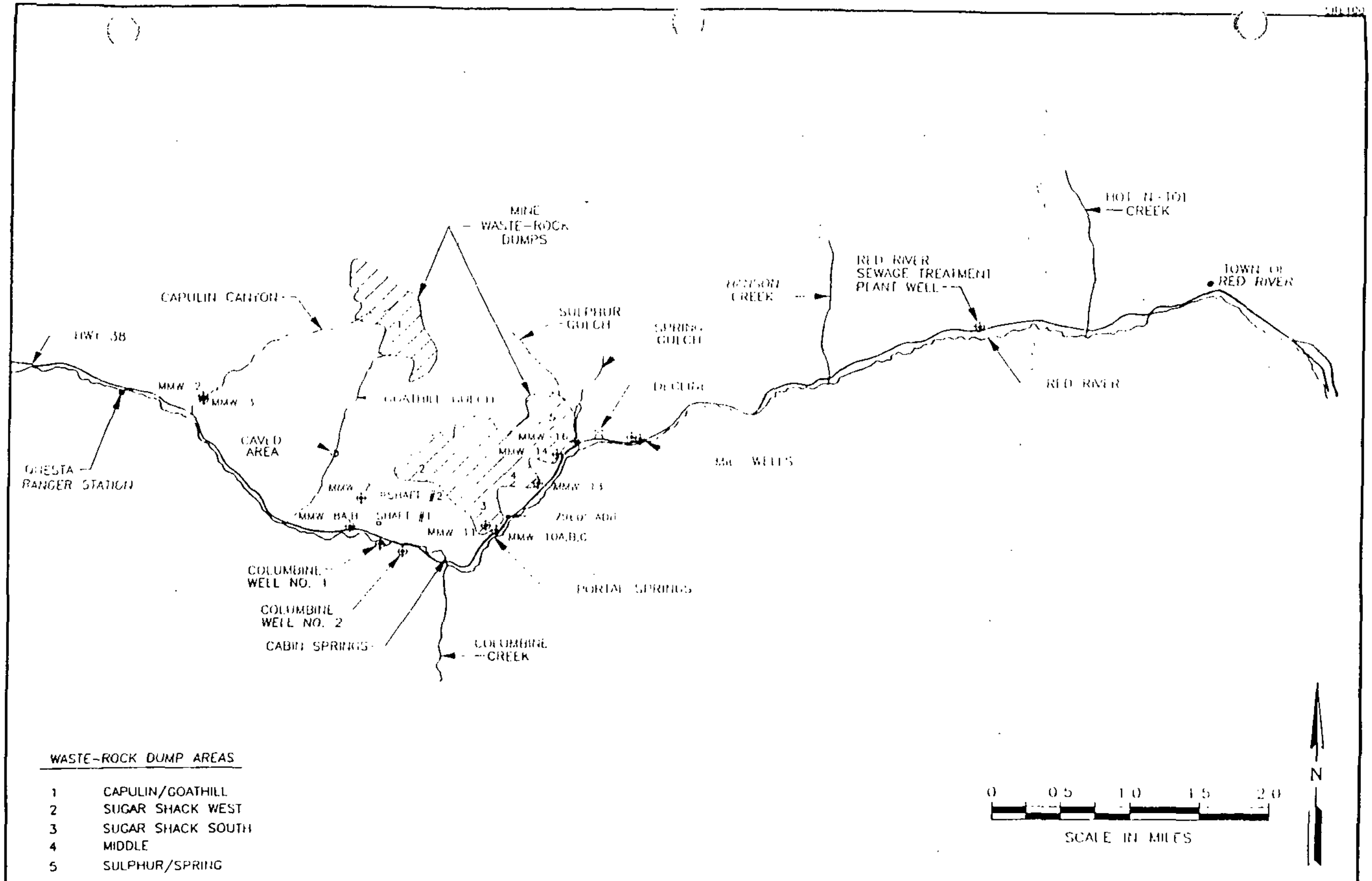

FIGURE: 2

SOUTH PASS RESOURCES, Inc.

PROJECT No. 001-06 | DATE 4/13/95

MINE AREA SITE MAP

Molycorp, Inc.

Questa, New Mexico

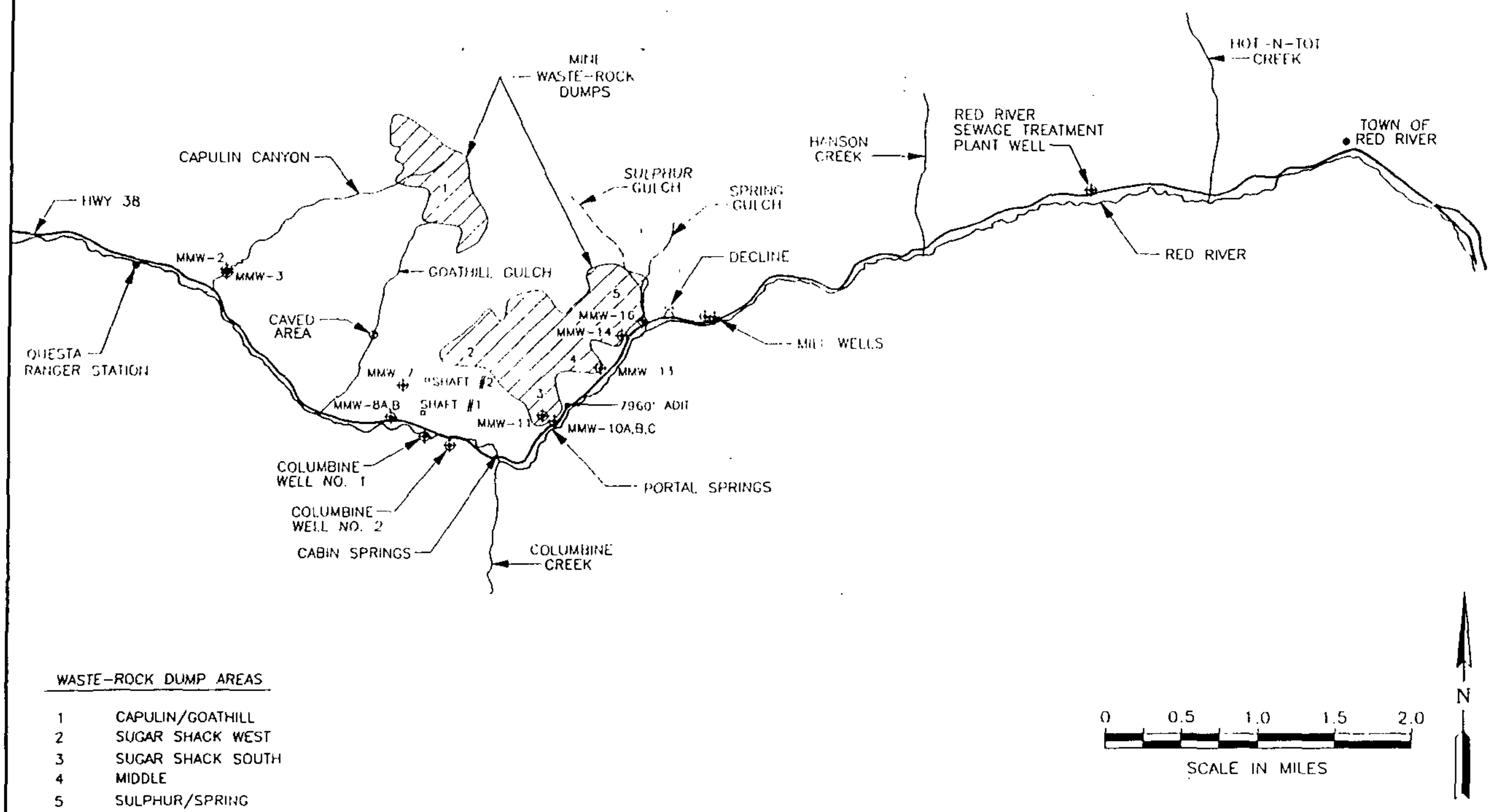

FIGURE: 2	SOUTH PASS RESOURCES, Inc.				MINE AREA SITE MAP Molycorp, Inc. Questa, New Mexico
	PROJECT No.: 001-06	DATE: 4/13/95	AUTHOR: J.C.K	DRAWN BY: M.O'M.	

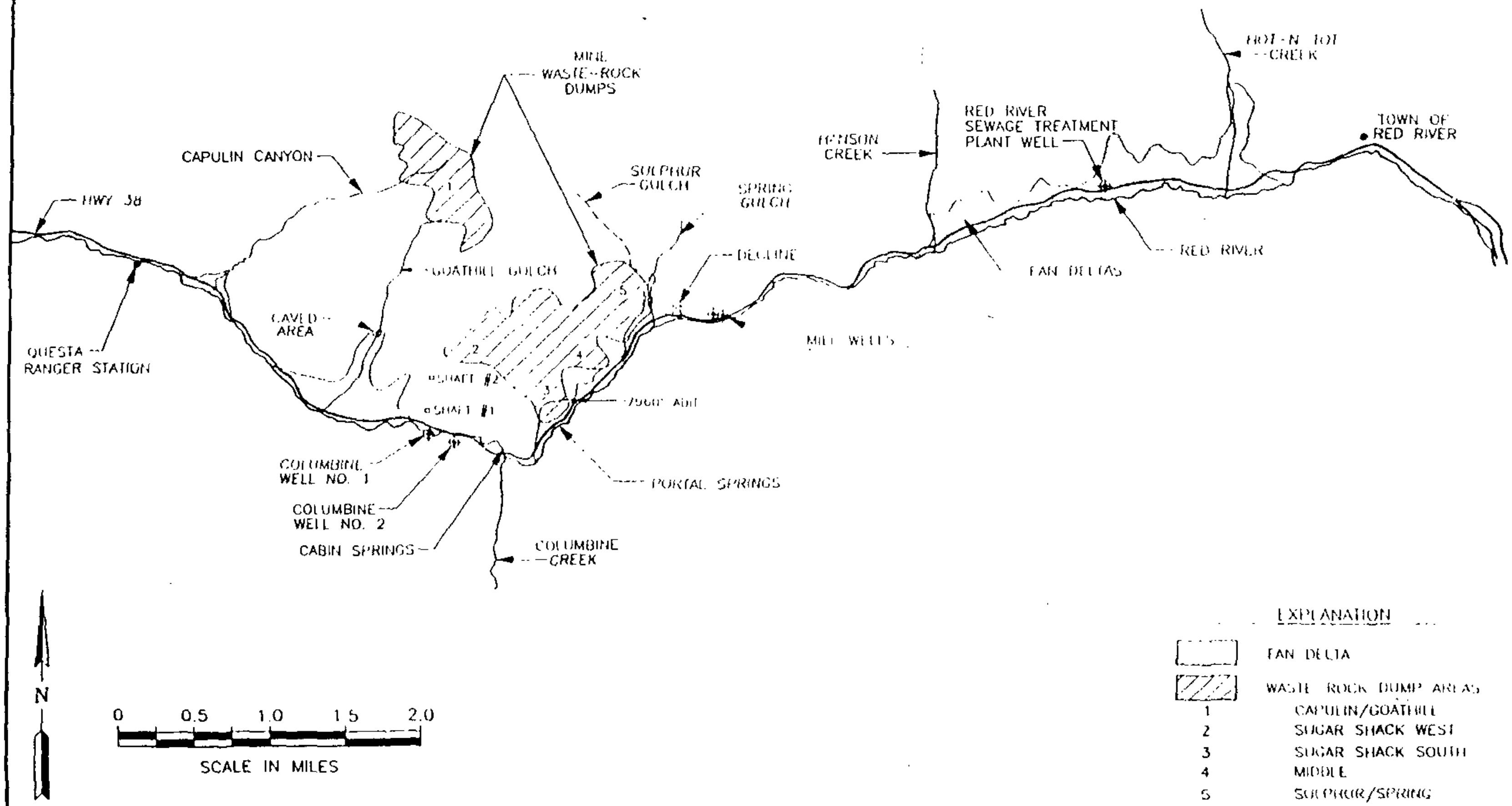

FIGURE: 4

SOUTH PASS RESOURCES, Inc.

PROJECT No.	DATE:	AUTHOR:	DRAWN BY
001-06	4/13/95	J.C.E.	M.O'M.

FAN DELTA AND MINE WASTE-ROCK LOCATIONS

Molycorp, Inc.
Questa, New Mexico

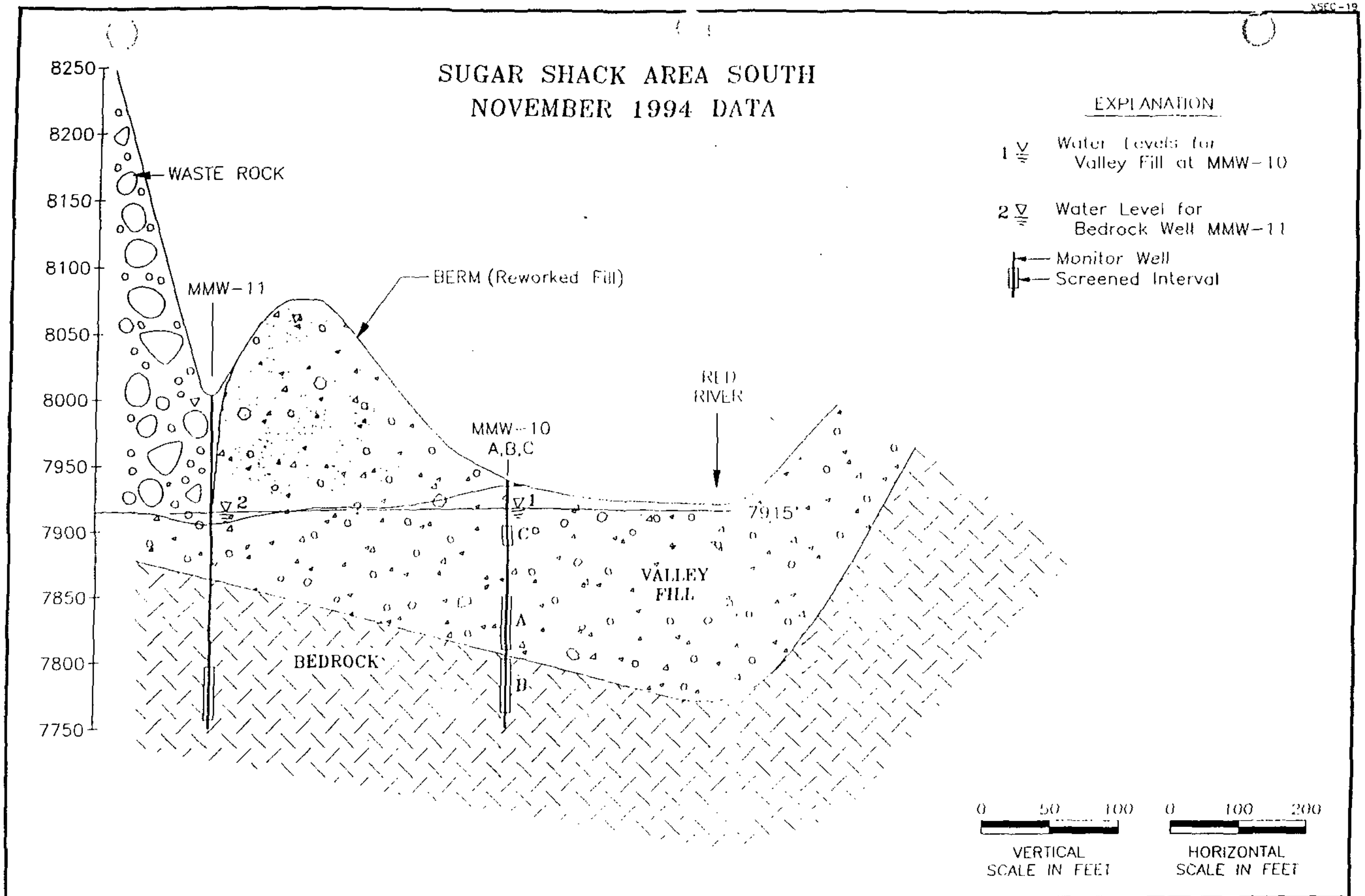

FIGURE: 5	SOUTH PASS RESOURCES, Inc.				HYDROGEOLOGIC CROSS-SECTION, SUGAR SHACK SOUTH
	PROJECT No.: 001-06	DATE: 4/13/95	AUTHOR:	DRAWN BY: M.O'M.	Mine Area – Molycorp, Inc. Questa, New Mexico

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normally carry some disseminated pyrite. Most of the ore mineralization was in the aplite and the andesite. Mine waste-rock ranges from fresh, weakly altered rock to rock consisting largely of quartz, clay, and pyrite (or its oxidized equivalent). Occasionally, rock fragments at the toe of the dump will disintegrate very easily because of the growth of intergranular gypsum precipitated from dump waters. Qualitative observation of waste-rock piles indicates that dump material ranges from clay to boulder sizes. The dump material shows "angle of repose" layering resulting from variations in time of the size fragments excavated. Downward flow of water in this unsaturated environment should be enhanced by the angle of repose layering.

B.2 GROUND-WATER RECHARGE

Factors to be evaluated in preparing estimates of ground-water recharge include: topography (elevation, degree of slope); surface material (outcrop, soil sediment); permeability and run-off characteristics of surface material; bedrock conditions in terms of infiltration characteristics, porosity, and hydraulic conductivity; and climate (temperature, precipitation, evaporation). Many of these parameters are not well defined in the Red River drainage area, but there are sufficient data to make some estimates of a hydraulic connection between ground water and the Red River.

The mine operations are located north of the Red River Valley where elevations range from 7,581 feet on the Red River opposite Capulin Canyon to 10,812 feet at the ridge north of the open pit, resulting in a relief of 3,221 feet. Excluding the relatively narrow flat to gently rolling valley floor, most of the topography is composed of steep to very steep slopes that are conducive to high rates of runoff. Major tributary canyons in the Mine Area have gradients on the order of 600 to 800 feet per mile.

The U.S. Soil Conservation Service (1982) defined four soil map units (as part of their soil survey of Taos County) in the Mine Area north of the Red River:

- Two of the soil units (Rock Outcrop/Ustorthentis Complex and Marosa Soil/Rock Outcrop Complex) are described as gravelly and/or sandy loams. These soils are characterized by rapid to moderate run-off with high erosion potential. Infiltration (number of inches per hour that water percolates downward in the soil) ranges from 0.6 to 6 inches. The soil units are described as complex because a significant percentage of the map area consists of outcrops of igneous and metamorphic rocks. Vegetative cover consists of Douglas fir, Engelmann spruce, and Ponderosa pine with an understory of Gambel oak, mountain brome, kinnikinnick, Kentucky bluegrass, Arizona fescue, and whortleberry.

- The third soil unit (Rock Outcrop/Badland Type) is associated with the hydrothermal scars and underlies much of the area north of the Red River

(Appendix A). This soil is described as extremely acidic (pH <4.5). It occurs along portions of all of the major drainages (Capulin, Goathill, Spring & Sulphur Gulch). Typically, slopes are steep and are nearly barren of vegetation. The Soil Conservation Service characterizes this unit as a soil that generates increasing sediment loads to tributary drainage as precipitation increases (very high run-off and erosion potential). Drainages that intersect the hydrothermal scar areas typically have mudflow deposits near their confluence with the Red River.

- The fourth soil unit (Cumulii Hoplobenolls) covers parts of the main valley floor. It generally consists of stratified gravelly sandy loams and gravelly clays. Infiltration of the soil is slow to moderate (0.2 to 2 inches per hour). Periodic flooding is the chief hazard here.

Rainfall estimates related to elevation and soil units in the Mine Area were prepared by the U.S. Soil Conservation Service (1982). For the lower elevation, below 9,000 feet, the annual precipitation is 18 inches; between 9,000 to 11,000 feet, annual precipitation is 35 inches. *In its report, the U.S. Soil Conservation Service indicates that annual snowfall can* exceed 100 inches in the mountains. Schilling (1956) had estimated 21 inches of annual precipitation for the same area. The bulk of the precipitation is winter snowfall with some thunderstorm contribution during the summer months. The average annual temperature is 40° to 42° Fahrenheit.

Several authors have attempted to estimate the distribution of precipitation among run-off, evapotranspiration, and ground-water recharge. Wilson and Associates (1978) estimated that in the mountainous areas of northern New Mexico, 3 to 10 inches of the precipitation contributed to run-off and the balance was distributed between evapotranspiration and recharge to ground water. Vail Engineering (1989) measured the areas of drainage basins for the major tributary to the Rio Grande, including the Red River, and calculated basin discharges from an equation based on drainage basin area and average annual winter precipitation. For the lower Red River basin (Zwergle Dam east of the Town of Red River to the Questa Ranger Station stream gauge), Vail calculated a discharge of 38.2 cubic feet per second (cfs). A review of flow discharges measured over a 12-year period [U.S. Geological Survey (USGS) data in Molycorp files for 1943 to 1955] shows that discharge ranges from 7.74 cfs to 262.5 cfs. In general, the higher flow rates occur in the April through July period and the lower rates over the balance of the year. Overall, this section of the Red River between the dam and the Ranger Station appears to be a gaining stream with substantially higher flow discharge at the downstream station.

River accretion studies by the USGS (in October 1965 and in 1988) were referenced by Smolka and Tague (1988) in their water quality survey of the Red River between Zwergle Dam and the Fish Hatchery. After correcting for tributary and diversion flows, they estimate that the net gains from ground water were 9.0 cfs (1965) and 9.1 cfs (1988) between Zwergle Dam and the Ranger Station gauge east of Questa. The Molycorp mill was not in operation in 1965 or 1988 and was not a factor in the diversion calculations. A review of the 1943-1955 flow data (Molycorp files) for these two gauges indicate that base flow (ground-water recharge) conditions ranged from 7.74 cfs to 13.9 cfs (an average of 11.04 cfs). This data set also shows that base flow conditions are typically in December and January, and Smolka and Tague's estimate for net gain to ground water may be too high. Vail (1989) used USGS stream flow data to estimate accretion to the Red River at nine locations from the Zwergle Dam site to the Bear Canyon area (near the Questa Ranger Station gauge). The segment from the Molycorp mill downstream to Bear Canyon is estimated to have an accretion of 6.6 cfs. Of this, 5.0 cfs comes from Columbine Creek, which leaves 1.6 cfs related to recharge from intermittent tributary drainages, seeps, and springs along both sides of the rivers.

Another approach to estimating drainage basin recharge to ground water utilizes the Maxey and Eakien (1949) approach. Their method estimates that 25 percent of the annual precipitation over the Mine Area drainage basin could contribute to recharge. Vail Engineering (1989) calculated areas for the Red River drainage basin and for the lower Red River basin (from Zwergle Dam to the Ranger Station). Using an area of 83.24 square miles at 25 percent of 21 inches annual precipitation (Schilling, 1956), the entire basin would contribute 32.25 cfs to ground water. That part of the entire drainage basin in the Mine Area represents about 6 percent of the total drainage basin. On the assumption of a uniform distribution of ground-water recharge (as an approximation), 1.94 cfs would be recharged to the ground water. Using Vail's (1989) estimate of the square miles for discrete elevation zones and 25 percent of the annual precipitation for each zone as recharge results in a higher estimate of 2.56 cfs ground-water recharge for the Mine Area drainage basin. SPRI (1993b), using a similar approach for the Mine Area drainage basin (Capulin Canyon to Spring & Sulphur Gulch), calculated a ground-water recharge of 1.45 cfs. If a water balance is assumed, this recharge equals accretion to the Red River.

A final approach to estimating recharge from ground water is to use the average of the baseflow from the 1943 to 1955 flow data (11.04 cfs) as an estimate of the total ground-water recharge for the basin. Again, with the assumption of an uniform distribution of recharge throughout the basin, the Mine Area portion of the drainage basin (6 percent of total area) would have contributed 0.66 cfs. This value is considerably lower than the precipitation-based estimates. The lower recharge values will be used here because there may be less error for a recharge estimate based on actual flow data than for estimates based on a precipitation approximation.

Vail Engineering's (1989) accretion study results in an estimate of 1.6 cfs of ground-water recharge in the river from both sides of the segment opposite the mine. This would result in about 0.8 cfs from the north (mine side) of the river, which is in fairly good agreement with the base flow estimate.

Molycorp records indicate when the deep underground mine was being developed, dewatering required between 250 and 500 gpm (0.57 to 1.14 cfs). The Smolka and Tague (1988) accretion study, during the time of mine development, shows a net accretion to the river from ground water of 9.0 cfs, similar to the pre-mine accretion of 9.1 cfs in 1965. Taken at face value, this suggests that the mine was dewatered from the deeper part of the ground-water flow system and did not appreciably, if at all, reduce accretion to the river from ground water. The explanation for this is that most of the ground-water recharge to the river may have come from the upper part of the ground-water system. In other words, the deep mine was not directly in the recharge zone. Schilling (1956), in his description of fracturing in the Sulphur Gulch area, indicated that many of the fractures (particularly sheeting type of fracturing related to contacts) tend to die out with depth. More water was probably in storage in the shallow, more open, and better interconnected fracture system close to the water table, and mineralization combined with lithostatic pressure effectively sealed much of the deeper level fractures. With lower hydraulic conductivity conditions at depth, a cone of depression (probably steep-sided) would develop over the deep mine. SPRI (1993b, 1994) concluded that the cone probably did not extend to the river.

The stability of the water levels in the monitor wells over the last five months, despite continuous dewatering of the underground mine (several hundred feet decline over the same period), supports the interpretation that a steep cone of depression occurs over the mine, and that the edge of the cone is north of the river. The wells close to the river could possibly be recharged at a rate which balances any loss (discharge) due to dewatering. Water-quality data from 1994 sampling of the river and of the monitor wells, in terms of dilution affect, is inconclusive because there is no historical water-quality data. Concentrations of sulfate in well water ranges from 700 to 1,300 mg/L while river water is typically less than 20 mg/L. As water-quality samples are taken over the next year, it may be possible to evaluate dilution affects, if any.

B.3 PRE-MINE WATER-TABLE CONFIGURATION

Based on Molycorp data (obtained in 1993), dewatering inflow for the older underground workings and for the open pit ranged from 15 to 30 gpm, which are very low flow rates. However, anecdotal evidence from mine workers active at the open pit indicate that an extensive water control program was in operation during the development of the pit and that these rates may be low. If these areas were below the water table, such rates could only be explained by very tight rock conditions in which virtually all the fractures were sealed.

Schilling's (1956) and Rehrig's (1969) descriptions of the fracture systems and field examination of rock exposures in the same area indicate that open fractures exist (some fracturing can be related to mine activities). It is also likely that these low flow rates can be attributed to perched fracture water above a regional water table. The deeper underground workings dewatered at 250 to 500 gpm. [For comparison, Newmont's Gold Quarry Mine in Nevada is in fractured sedimentary rock and dewaters at 50,000 gpm (Carrillo, 1993).] However, if the fractures in a mineralized zone were partly sealed by mineralization/clay gouge and/or poorly interconnected, then 500 gpm, even below the water table, would not be unreasonable. It is possible that the open pit and most of the older underground workings near Sulphur Gulch (down to 7,800 to 7,900 feet) were above the regional water table and that the inflows were from perched water. Currently, this inflow from the open pit and the older underground mine drains though a borehole into the deeper mine workings.

If the gaining stream model is used with the equipotential lines (contours of equal water-level elevation) nearly normal to the flow direction of the river, such a contour surface would allow for most of the old workings and the pit to be relatively dry and above the regional water table. The Moly Tunnel (7,960 adit) would be at the water table at an elevation of 8,000 feet. Construction of the 7,960 adit did not produce much water and, therefore, the 8,000-foot water-level contour might have curved more to the north. This water-table surface would have a southwesterly gradient of 0.036 foot/foot in this very simplified configuration. If the equipotential lines were parallel to the river, most of the old workings and part of the open pit would have been below the pre-mine water table.

A simplified water-table surface with the equipotential lines at a right angle to the river can be used to estimate the elevation of the water table in various areas of the underground workings. For example, the water level would continue to rise in the caved area above the underground workings in the Goathill Gulch area to an elevation of approximately 7,840 feet. At Shaft No. 1, the elevation would be about 7,820 feet and at Shaft No. 2, it would be closer to 7,850 feet. With respect to the old Moly Tunnel (7,960 adit), a conservative position would place it just below the water table at about 8,000 feet.

Another element in the water-table surface configuration is the additional recharge from seepage barriers to the mine through the caved area. This recharge currently amounts to about 70 gpm captured by the seepage barriers constructed on Capulin and Goathill Gulches. An additional 30 gpm drains from the open pit through a borehole in the old underground mine to the deeper workings. This amount of seepage water is occasionally strongly augmented by surface water related to storm discharge and snow melt such that recharge to the caved area can exceed several hundred gpm. How much of this water actually reaches the caved area is unknown since it is a surface discharge and a certain amount must be lost to evaporation or infiltration to the vadose zone. (In the vadose zone, the water would be bound by surface tension in intergranular voids or micro-fractures.) It is possible that the additional recharge might cause some mounding of the water table surface, particularly in the caved area, and locally a slightly steeper gradient. A concern here is that water-level mound in the caved area might extend to the valley-fill in Goathill Gulch from which it could more easily reach the river.

Rate of Rise for the Water Table

On May 19, 1994, the water level in the mine workings was at 7,600 feet. According to Molycorp records, the caved area began to fill by October 20, 1992. Using the elevation of the bottom of the caved area (7,226 feet) and the time since filling began (549 days), the rate of rewatering is 0.68 foot/day. The actual daily rate values range from less than 0.68 to as much as 2.0 feet/day, depending on seasonal recharge conditions. However, if the 0.68 foot/day is used as the rate, it would take 147 days (from May 1994) for the water level to rise to the down-gradient elevation (7,700 feet) of the Red River. (This assumes a southwestern gradient based on the normal contour configuration in the caved area at Goathill Gulch). In other words, after 147 days (0.4 year) from May 1994, there would be a slight gradient from the cave area toward the river. Using the same rate of 0.68 foot/day, it would take 0.97 year to reach the postulated water-table elevation of 7,840 feet in the caved area. However, as noted in the previous paragraph, localized high recharge rates in the caved area could cause mounding and water would be higher and at an earlier date than the 0.68 foot/day rate predicts. In the case of the Moly tunnel (7,960 feet), it would require 1.61 years for the water level to reach 8,000 feet and begin to flow down to the adit.

Monitor wells constructed in 1994 were designed to capture tributary discharges to the valley-fill and bedrock aquifers. Not enough wells were sited in a single aquifer to evaluate flow directions or hydraulic gradients.

B.4 AQUIFER TESTS

An aquifer test conducted in the valley-fill at MMW-10A resulted in a calculated transmissivity of 123,200 gallons per day per foot (gpd/ft) and a hydraulic conductivity of 1,141 gpd/ft^2 (based on an aquifer thickness of 108 feet). These are reasonable values for the coarse sand and gravel encountered in this well. However, the maximum pump yield was 140 gpm, and the aquifer was not stressed.

Almost all of the bedrock wells went dry during development (air-lift). Bladder pumps were utilized in sampling these wells, and yields were typically a few gallons per minute or less. The exception to the low yield during development was MMW-11, which yielded 60 gpm with less than one (1) foot of drawdown. The high yield probably resulted from this well being located close to a north-south fracture zone. An estimate for transmissivity based on the specific capacity:

$$\left(\frac{Q}{s}\right) = \left(\frac{60gpm}{1foot}\right)$$

and utilizing an equation developed by Huntley et al. (1992) for fractured rock

$$T = K\left(\frac{Q}{s}\right)^{1.18}$$ where K is a conversion factor from their Table 1

resulted in a transmissivity of 4,877 ft^2/d, or 36,481 gpd/ft. (Note: The factor to convert from ft^2/d to gpd/ft is 7.48.)

The thickness of the bedrock aquifer is unknown. Using the saturated thickness at the well (58 feet), an estimated hydraulic conductivity (K) is 629 gpd/ft^2. This is probably close to a maximum value (thickness is too small), but still lies within the upper range of K values for fractured igneous rock (Freeze and Cherry, 1979, Table 2.2).

Another approach to estimating hydraulic conductivity uses the decline in water level at the underground mine during the current dewatering phase and dates of measurement on a time-drawdown plot. Data were plotted on semi-log pager and the Cooper-Jacobs equation was used to calculate transmissivity.

$$T = \left(\frac{264Q}{\Delta s}\right)$$

This calculation resulted in a transmissivity of 2,424 gpd/ft and a hydraulic conductivity of 5.09 gpd/ft^2 (the latter is based on a thickness of 476 feet or the difference between the pre-dewatering water-level and the top of the Grizzly level at the underground mine). The Cooper-Jacobs equation was developed for porous media. Its application to bedrock data assumes that over a large enough volume of rock ("large enough" is not specified), fractured rock can be approximated by a porous media formula.

The two values for hydraulic conductivity reported here are at best rough estimates. These results suggest that hydraulic conductivity ranges over two orders of magnitude from fairly tight rock to permeable fracture zones. A compilation of flow velocity based on simple analytical equations using single hydraulic conductivity values does not lead to reliable estimates for travel time. Even if the estimate was close to a true travel time, open fault zones at an angle to the regional gradient can move ground water more rapidly and in a different direction from the regional flow direction. Estimates of flow velocity and travel time, based on water quality (from known sources) and isotopic data, may have more validity (when the data from such studies become available) than hydrogeological approximations.

B.5 GROUND-WATER TRANSPORT

With the currently available information, it is not possible to make meaningful quantitative estimates for the velocity of ground water through the fractured bedrock. Tracer tests in sets of nearby boreholes would probably allow for an estimate of ground-water velocity through fractures. For these tests, the distances between boreholes and their relationship to mapped fractured systems would have to be considered. However, as indicated in previous sections, water chemistry combined with isotope data might lead to better estimates for velocity.

Seepage velocity formulas are based on advection in granular material, not fractured rock. Moreover, conceptual models for fracture flow include an equivalent porous media model that treats fractured rock as if it were a granular, porous medium. The rationale is that if the fracture spacing is small (compared to the scale of the system being studied), the model leads to a reasonable estimate of regional flow. The model is not an accurate representation of local conditions (e.g., an open fault that diverts flow at some angle to the regional system).

Using the caved area (located on Goathill Gulch) above the deep underground workings as a source and published values for hydraulic conductivity and porosity for fractured rock (Freeze and Cherry, 1979), rough estimates of travel time from the mine to the river can be made. According to Freeze and Cherry (1979), the range of hydraulic conductivity for fractured igneous and metamorphic rocks is 10^{-1} to 10^{3} gallons/day/ft^{2} and for permeable basalt 1 to 10^{5} gallons/day/ft^{2}. The porosity range for fractured crystalline rock is 0 to 10 percent, and for fractured basalt 5 to 50 percent.

The seepage velocity formula is:

$$V = \frac{Ki}{7.48 n_e}$$

where:
- V = seepage velocity, in feet/day;
- K = hydraulic conductivity, in gallons/day/square foot;
- i = hydraulic gradient, in feet/feet;
- n_e = porosity, as a percent; and
- 7.48 = gallons per cubic foot.

D.4 Tritium Isotope Analyses

Tritium is the heavy isotope of hydrogen (^3H) that disintegrates radioactively to helium (^3He) at a half-life of 12.3 years (Mazor, 1991). After 12.3 years, half of the initial amount of tritium has decayed to helium. The concentration of tritium in water is expressed in tritium units (TU), which is a ratio of tritium to hydrogen atoms. The T/H ratio of 10^{-18} is defined as one TU.

Tritium is produced naturally in the atmosphere by the radioactive decay of nitrogen (^{15}N). Tritium atoms are oxidized to water, become mixed with precipitation, and eventually enter the ground-water system. Natural production of tritium introduces about 5 TU to precipitation and surface water. In the saturated zone, water is isolated from the atmosphere and the tritium concentration drops due to radioactive decay.

Using a measured value for tritium and a half-life curve (tritium concentration as a function of time), however, does not lead to a precise age for the ground water. As a consequence of recharge, water accumulates and mixes over time in the aquifer such that the age obtained from tritium data is an average or effective age (Mazor, 1991). Smith and Wheatcraft (1993) refer to this "ground-water age" as an estimate of the subsurface residence time of ground water since it was isolated from the atmosphere and soil gas.

Hydrogen bomb tests which began in 1952 in the northern hemisphere added large amounts of tritium to the atmosphere, completely masking the natural tritium input. The peak of man-made tritium production was in 1963, which was the same year that atmospheric testing was halted by international treaty. Since this testing stopped, the tritium content of precipitation has been declining. The tritium content of precipitation has been measured at a worldwide network of stations since the end of testing. These data are normally presented as concentration curves of the annual weighted average of tritium since 1961. Concentration curves from the network show:

- values in the northern hemisphere that are much higher than those in the southern;
- summer peaks and winter lows related to the annual redistribution of tritium in the atmosphere; and
- significant variance from one station to another in terms of the tritium concentrations.

As noted earlier, due to mixing of recharge waters in the aquifer over time, the age of a ground-water sample is an effective age. Further estimates of an effective age are only valid if it is known that the water is derived from a single source/single aquifer system. If older ground water from a bedrock aquifer were to mix with younger water from an adjacent shallow aquifer, the effective age would only reflect dilution. If the appropriate concentration curve is available (i.e. from a geographically nearby station), and if the sample was collected from a single source/aquifer unit, then an effective age can be assigned. According to Mazor (1991), *water that has zero tritium (in practice, <0.5 TU) has a pre-1952 age.* Water that has significant tritium concentrations (in practice, >10 TU) is of post-1952 age. Water that has concentrations between 0.5 and 10 TU seems to be a mixture of pre- and post-1952 water.

Water samples for tritium analyses were collected in 1-liter brown glass bottles. No head space was allowed in these samples. Six samples were collected in May 1994 and three in November 1994. All samples were sent to Chempet Research Corporation in Moorpark, California for analysis. The enriched tritium procedure allows for a precision of 0.8 TU. The results of the tritium analyses for the May 1994 sample are presented below. (The results of the November 1994 analyses are discussed in Section 4.0 of the main text of this report.)

Results of Tritium Analyses

Sample No.	Site Description	TU ± 2σ
CCS-1	seepage from the base of the Capulin Canyon mine waste-rock dump	15.1 ± 2.2
CCS-2	fresh water spring, west side of Capulin Canyon	12.3 ± 1.8
CCS-3	bedrock seep in an adit, west side of Capulin Canyon	8.0 ± 1.4
GHS-1	seepage from the base of the Goathill Gulch waste-rock dump	16.7 ± 2.4
GHS-3	bedrock seep on the divide near the head of Goathill Gulch	8.5 ± 1.4
Cabin Springs	seeps on the north bank of the river behind the Cabins	17.5 ± 0.6
MMW-11	bedrock well near Sugar Shack South waste-rock dump	16.9 ± 0.6
MMW-3	bedrock well in lower Capulin Canyon	4.38 ± 0.14

Given that the open pit operation (which was the source of the dump material) began in the late 1960s, the tritium data, supported by water chemistry, indicates most, if not all, of the water collected from the dump seepage at the head of Capulin and Goathill Canyons is derived from the dumps. The values greater than 10 TU for the two waste dump samples indicate post-1952 water. Without the appropriate tritium concentration curve, a more precise effective age cannot be made.

Water from the freshwater spring that flows at 12 gallons per minute (gpm) may also be post-1952, but considering the standard deviation, it could be a mixture of older perched water and post-1952 water. The two bedrock seeps appear to be a mixture of pre- and post-1952 water. In the case of the Goathill Gulch sample, the seep lies several hundred feet below the Capulin/Goathill mine waste-rock dumps and may include older perched water and dump leachate that has infiltrated the bedrock. Likewise, the adit sample may include water from pre- and post-adit fractures (caused by excavation of the adit). The tritium values for these bedrock samples reflect dilution rather than effective age.

The average tritium concentrations for precipitation per year have been collected at various world-wire weather stations since 1961. The weather station closest to the Red River area is Flagstaff, Arizona; however, telephone calls to the Flagstaff weather station and several hydrologists who use tritium data failed to locate such a database. Mazor (1991) illustrates plots of TU against years for several different stations. The nearest station in terms of similar latitude is Hatteras, North Carolina, on the east coast. Although the average tritium concentration curves from the northern hemisphere stations are similar (peaks and troughs roughly correspond and their slopes are similar), the absolute value for TU in any one year varies by an order of magnitude or less depending on station location. These absolute values are related to atmospheric circulation patterns. To obtain a reliable estimate of the significance of the TU values for the mine samples, a station about the same latitude but in the western United States would be preferable.

As an example of the application of tritium results, using the Hatteras data from Mazor (1991), precipitation infiltrating the ground in 1970 would have contained about 75 TU. In the intervening 24 years (1970 to 1994), the tritium would have radioactively decayed, leaving about 22 percent (Mazor, 1991, Figure 10.1) of the tritium retained in a 1994 water sample. Assuming no mixing of older and younger water, there should be about 16.5 TU left in the sample. This value is within the range of the "young" water samples collected in the Mine Area (e.g. CCS-1, GHS-1, Cabin Springs, and MMW-11). If the Hatteras data can be applied here, these results, combined with the water chemistry of these samples, indicate water stored in the waste-rock dumps (constructed in the 1970s) could be a source. However, with the limited amount of site-specific hydrogeological data available, a natural acidic seepage source following a short flow path (from recharge to discharge zone) or traveling parallel to a highly permeable zone (short travel time) can not be entirely ruled out. The relatively high TU value for the spring at CCS-2 may be an example of a short flow path.

Pre-1952 ground water contained about 5 TU. In the intervening 42 years (1952 to 1994), approximately 8 percent of the tritium would be retained which corresponds to 0.4 TU.

APPENDIX E

If ground water was recharged with pre-1952 water without any subsequent mixing, it should contain about 0.4 TU. Samples such as MMW-3, CCS-3, and GHS-3 or those with results in the 0.5 to 10 TU range are mixtures of young (post-1952) and older (pre-1952) water (e.g. an average value for a mixture of 16.5 TU and 0.4 TU water is 8.45 TU).

D.5 Stable Isotope (Lead and Strontium) Study

Eight water samples from the Mine Area (four from Capulin Canyon, two from Goathill Gulch, one from the Red River, and one from Hot-N-Tot Canyon) were analyzed for lead and strontium isotopic composition (Chempet, 1994). The limited objective of this study was to evaluate if any isotopic differences between natural acidic ground water and acidic mine drainages could be detected. To demonstrate statistically significant differences, a much larger number of samples, taken at different times of the year to assess seasonal effects and from varied geologic settings, would need to be collected. Furthermore, isotopic analyses of bedrock, dump, and alluvial source materials would have to be made to evaluate water/rock interactions and causes for any detected differences.

Both strontium and lead consist of radiogenic and non-radiogenic isotopes. In general, as the result of radioactive decay of the parent element, the radiogenic component increases with time. However, the ratio of radiogenic to non-radiogenic isotopes in any given sample containing lead or strontium is not a fixed value. The value depends on the history of the sample: how much of the radioactive precursor was present in the sample originally and how much of the radioactive element of strontium or lead has been removed from or added to the sample at a later time.

Three stable isotopes of lead (Pb) -- 206 Pb, 207 Pb, and 208 Pb -- are radiogenic and are derived by radioactive decay of 238 uranium, 235 uranium, and 232 thorium, respectively. Another stable isotope, 204 Pb, is non-radiogenic and is used as a reference isotope in the lead system. Strontium (Sr) has four naturally occurring stable isotopes -- 88 Sr, 87 Sr, 86 Sr, and 84 Sr. Only one of these (87 Sr) is radiogenic. It is derived from the radioactive decay of 87 rubidium. The reference isotope is the non-radiogenic 86 Sr, and the ratio of 87 Sr to 86 Sr (87 Sr / 86 Sr) is used in evaluating biogeological processes. The purpose of both lead and strontium isotope studies, other than age of the sample, has been to identify probable source material(s), mixing of water from multiple sources, and, from this, flow paths in a ground-water system.

Isotopic studies which focus on a particular mineral (such as galena from an ore deposit) may result in a very narrow range of ratios (age) which are statistically indistinct. However, when ground water or surface water which has reacted with a greater variety of rock types of different ages and different histories is examined isotopically, the range of values widens and isotopic distinctions may be evident. At Questa, Oligocene to Miocene

APPENDIX E

TABLE D1

1994 MONITOR WELL WATER QUALITY DATA FOR MINE AREA

MOLYCORP, INC. - QUESTA, NEW MEXICO

MONITOR WELL	SAMPLE DATE 1994	WELL TD (feet)	Corrected DEPTH TO WATER (feet)	DEPTH TO PUMP INTAKE (feet)	pH (1)	CONDUC-TIVITY(1) (uhmos)	TEMP.(1) (°C)	CARBO-NATE (mg/L)	BICARBO-NATE (mg/L)	HYDR-OXIDE (mg/L)	TOTAL ALK (mg/L)	CHLORIDE (mg/L)	FLUORIDE (mg/L)	SULFATE (mg/L)
MMW-2	8-Nov	68	31.69	50	4.90	3,680	7.9	<1	<1	<1	<1	6.8	24.0	2,100
MMW-3	7-Nov	140	27.76	80	7.50	3,970	10.9	<1	222	<1	222	5.8	2.59	1,700
MMW-7	7-Nov	161	61.11	120	4.40	9,490	17.2	<1	<1	<1	<1	21	1.12	10,400
DUP-11A (2)	7-Nov	NA	NA	NA	NA	NA	NA	<1	<1	<1	<1	21	0.98	10,500
MMW-8A	8-Nov	178	96.77	140	7.00	2,860	8.4	<1	165	<1	165	8.7	2.72	1,100
MMW-8B	8-Nov	129	96.03	112	6.40	1,780	7.1	<1	19	<1	19	5.6	1.83	730
MMW-10A	8-Nov	144	21.70	100	5.80	2,400	7.8	<1	<1	<1	<1	27	11.2	1,100
DUP-12B (3)	8-Nov	NA	NA	NA	NA	NA	NA	<1	<1	<1	<1	26	7.96	1,100
MMW-10A (4)	19-Nov	NA	NA	NA	NA	NA	NA	<1	<1	<1	<1	26	8.28	1,200
MMW-10B	7-Nov	189	21.57	140	7.90	2,250	10.1	10	<1	66	76	28	12.2	1,100
MMW-10C	8-Nov	50	21.80	40	4.70	2,000	11.8	<1	<1	<1	<1	20	15.4	880
MMW-11	7-Nov	184	86.71	150	5.60	2,450	15.7	<1	<1	<1	<1	22	17.6	1,300
MMW-13	8-Nov	145	105.98	130	7.90	2,280	8.9	<1	200	<1	200	14	1.67	770

NOTES:

(1) pH, CONDUCTIVITY AND TEMPERATURE WERE RECORDED WHEN SAMPLED.

(2) - Dup 11A = DUPLICATE SAMPLE FOR MMW-7

(3) - Dup 12B = DUPLICATE SAMPLE FOR MMW-10A

(4) - *SAMPLED AFTER AQUIFER TEST*

NA - Not Available

SOURCE: SAMPLES TAKEN BY SPRI, ANALYTICAL RESULTS FROM MOLYCORP.

TABLE D1
1994 MONITOR WELL WATER QUALITY DATA FOR MINE AREA
MOLYCORP, INC. - QUESTA, NEW MEXICO

MONITOR WELL	TDS (mg/L)	SILVER (mg/L)	ALUMINUM (mg/L)	ARSENIC (mg/L)	BARIUM (mg/L)	BERYLLIUM (mg/L)	CALCIUM (mg/L)	CADMIUM (mg/L)	COBALT (mg/L)	CHROMIUM (mg/L)	COPPER (mg/L)	IRON (mg/L)	MERCURY (mg/L)
MMW-2	3,400	<0.10	63.5	<0.005	<0.010	0.015	501	0.024	0.280	<0.010	0.088	50.8	<0.0002
MMW-3	2,900	<0.10	0.75	<0.005	0.047	<0.004	567	0.0024	0.089	<0.010	<0.010	0.076	<0.0002
MMW-7	16,000	<0.50	943	<0.05	0.108	0.104	544	0.096	4.91	0.193	4.84	384	<0.0002
DUP-11A (2)	16,000	<0.50	961	<0.05	0.074	0.122	534	0.092	4.99	0.17	5.04	375	<0.0002
MMW-8A	2,200	<0.10	<0.05	<0.005	0.103	<0.004	466	0.002	<0.010	<0.010	<0.010	2.84	<0.0002
MMW-8B	1,100	<0.10	0.44	<0.005	0.016	<0.004	206	<0.0005	<0.010	<0.010	<0.010	<0.050	<0.0002
MMW-10A	1,700	<0.10	33.4	<0.005	<0.010	0.008	275	0.028	0.148	<0.010	0.558	<0.050	<0.0002
DUP-12B (3)	1,700	<0.10	34.2	<0.005	<0.010	0.008	270	0.024	0.137	<0.010	0.58	<0.050	<0.0002
MMW-10A (4)	1,700	<0.010	31.6	<0.005	<0.010	0.006	245	0.0224	0.141	<0.010	0.534	0.086	<0.0002
MMW-10B	1,800	<0.10	8.74	<0.005	0.034	0.007	347	0.025	0.074	<0.010	0.179	0.101	<0.0002
MMW-10C	1,400	<0.10	31.1	<0.005	0.014	0.007	204	0.026	0.106	<0.010	0.38	<0.050	<0.0002
MMW-11	2,000	<0.10	56.3	<0.005	0.016	0.013	276	0.036	0.266	0.036	0.919	0.129	<0.0002
MMW-13	1,400	<0.10	<0.05	<0.005	0.036	<0.004	316	<0.0005	0.013	<0.010	<0.010	0.198	<0.0002

NOTES:

(1) pH, CONDUCTIVITY AND TEMPERATURE WERE RECORDED WHEN SAMPLED.

(2) - Dup 11A = DUPLICATE SAMPLE FOR MMW-7

(3) - Dup 12B = DUPLICATE SAMPLE FOR MMW-10A

(4) - SAMPLED AFTER PUMP TEST

SOURCE: SAMPLES TAKEN BY SPRI, ANALYTICAL RESULTS FROM MOLYCORP.

Values used in
Fig. C-3

TABLE D1

1994 MONITOR WELL WATER QUALITY DATA FOR MINE AREA

MOLYCORP, INC. - QUESTA, NEW MEXICO

MONITOR WELL	POTASSIUM (mg/L)	MAGNESIUM (mg/L)	MANGANESE (mg/L)	MOLYBDENUM (mg/L)	SODIUM (mg/L)	NICKEL (mg/L)	LEAD (mg/L)	ANTIMONY (mg/L)	SELENIUM (mg/L)	SILICON (mg/L)	THALLIUM (mg/L)	VANADIUM (mg/L)	ZINC (mg/L)
MMW-2	10.8	137	52.1	<0.02	64.6	0.61	<0.002	<0.05	<0.05	20.3	<0.005	<0.010	9.48
MMW-3	7.5	96.2	34.5	<0.02	103.	0.236	<0.002	<0.05	<0.005	7.6	<0.005	<0.010	1.36
MMW-7	12.0	1250	72.1	<0.10	175	10.5	0.10	<0.25	<0.025	22.7	<0.005	0.104	11.7
DUP-11A (2)	12.1	1230	73.3	<0.10	178	10.7	0.06	<0.25	<0.025	22.6	<0.005	0.106	11.9
MMW-8A	3.8	85.6	7.15	<0.02	41.5	<0.020	<0.002	<0.05	<0.005	11.1	<0.005	<0.010	<0.050
MMW-8B	2.9	55.5	0.202	<0.02	33.9	0.059	<0.002	<0.05	<0.005	17.3	<0.005	<0.010	0.211
MMW-10A	2.8	77.9	13.8	<0.02	26.5	0.325	<0.002	<0.05	<0.005	14.3	<0.005	<0.010	2.29
DUP-12B (3)	2.5	76.7	12.8	<0.02	26.4	0.293	<0.002	<0.05	<0.005	14.0	<0.005	<0.010	2.07
MMW-10A (4)	3.7	69.7	13.1	<0.02	25.6	0.279	0.004	<0.05	<0.005	14.1	<0.005	<0.010	2.68
MMW-10B	3.5	80.3	8.55	<0.02	25.8	0.201	0.021	<0.05	<0.05	12.8	<0.005	<0.010	1.5
MMW-10C	2.8	75.2	16.3	<0.02	20.2	0.0347	<0.002	<0.05	<0.005	9.9	<0.005	<0.010	3.2
MMW-11	3.4	133	31.7	<0.02	25.5	0.593	0.086	<0.05	<0.005	14.2	<0.005	<0.010	5.0
MMW-13	5.4	38.7	1.02	0.05	30	<0.020	<0.002	<0.05	<0.005	8.8	<0.005	<0.010	0.222

NOTES:

(1) Ph, CONDUCTIVITY AND TEMPERATURE WERE RECORDED WHEN SAMPLED.

(2) - Dup 11A = DUPLICATE SAMPLE FOR MMW-7

(3) - Dup 12B = DUPLICATE SAMPLE FOR MMW-10A

(4) - SAMPLED AFTER PUMP TEST

SOURCE: SAMPLES TAKEN BY SPRI, ANALYTICAL RESULTS FROM MOLYCORP.

These values used in calculating slopes in Fig. C-3

TABLE D4
WATER QUALITY OF MINE WATER
MOLYCORP, INC. - QUESTA, NEW MEXICO

Sample Location	Shaft No. 1 Shallow	Shaft No. 1 Deep (mg/L)	Shaft No. 1 Top (mg/L)	Shaft No. 1 1000 ft (mg/L)	Shaft No.2 (mg/L)	Decline (mg/L)	Decline (mg/L)	Open Pit (mg/L)
Date	NA	NA	10/94	10/94	NA	NA	10/94	10/94
pH	6.9	7.7	6.96	6.96	7.2	7.5	6.7	3.1
Aluminum	NA	NA	0.5	0.5	<0.5	1.2	1.0	303.0
Sulfate	1,455	1,480	1,665	1,720	1,345	1,004	1,720	11,561
TDS	3,072	3,386	3,276	3,584	3,164	2,468	3,507	24,420
Fluoride	NA	13.1	NA	NA	5.0	7.10	NA	NA
Cadmium	<0.005	0.01	<0.01	<0.01	<0.005	<0.005	<0.01	0.304
Lead	<0.10	<0.10	<0.10	<0.10	<0.10	<0.1	<0.10	<0.10
Iron	0.30	<0.05	50.0*	46.2*	<0.05	<0.05	39	164.0
Manganese	8.6	15.5	11.5	12.0	5.10	1.20	13.30	408.0
Zinc	1.3	0.30	0.283	1.54	2.70	2.80	1.52	70.1
Copper	<0.01	0.02	0.03	0.03	<0.01	<0.01	0	6.7
Molybdenum	2.70	2.20	2.22	2.22	1.80	1.20	2.44	0.41
Arsenic	<0.01	<0.01	NA	NA	<0.01	<0.01	NA	NA
Mercury	<0.20	<0.20	NA	NA	<0.20	<0.20	NA	NA

* Total Iron

001-05.XLS